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JOB PERFORMANCE AID SELECTION ALGORITHM: DEVELOPMENT AND APPLICATION

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JOB PERFORMANCE AID SELECTION ALGORITHM:
DEVELOPMENT AND APPLICATION

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Reviewed by
R. E. Blanchard

FOREWORD

This research and development was conducted in response to Navy Decision Coordinating Paper, Performance Aids Test and Evaluation (NDCP-Z0828-PN), under the sponsorship of the Director, Naval Education and Training (OP-099). The effort is a preliminary attempt to define a Job Performance Aids (JPAs) selection algorithm for an integrated personnel system (IPS).

The algorithm has been used to determine major JPA technology gaps and to select specific JPA systems for test and evaluation. Work is continuing to define a complete algorithm and guidelines for determining trade-offs among aiding, training, selection, and job design technologies. The algorithm in its final form will be validated with the IPS multivariable model in a field test as part of the aforementioned advanced development evaluation effort.

DONALD F. PARKER
Commanding Officer

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SUMMARY

Problem

The Navy and the other services face increased personnel and training costs and declining personnel force levels and skills. At the same time, however, new equipments are designed to be operated and maintained by more highly skilled, better trained personnel. Aiding technology as an adjunct to training and selection is now being considered as a way to meet the Navy's operational maintenance requirements with available manpower.

There has been some difficulty, however, in selecting the best job performance aids for the tasks, environment, and personnel needs of any particular weapon system. In the past this has been a major impediment to the full utilization of job performance aid (JPA) technology. Several JPA selection models have been developed but none has received wide acceptance. Most of them do not adequately consider the impact of JPA selection on training, work force capabilities, and the practicalities of Navy utilization.

Purpose

The purpose of the study was to develop an algorithm for selecting JPA format and content that considers training, media, and work-center job designs. The primary objectives of the development were (1) to identify JPA research and technology gaps, (2) to identify candidate JPA systems for Navy personnel, maintenance, and training trade-off analyses, (3) to select specific JPA systems for test and evaluation, and (4) to identify complementary training levels for selected JPA systems.

Approach

A nine-step selection algorithm was developed to identify the most appropriate JPA/training combination for the JPA system level of a tri-level conceptual organization of JPA technologies. The nine decision steps were based on seven primary decision criteria (aptitude, job experience, task type, task complexity, equipment type, equipment complexity, and degree of proceduralization) established in the literature as critical to on-the-job performance. A graphic representation of the decision steps and amplifying guidelines for exercising the algorithm were developed and applied to three performance-aiding scenarios and two Navy ratings.

Results

The selection algorithm was used to identify candidate JPA systems for each skill level of the Integrated Personnel System (IPS) model (Blanchard & Laabs, 1978) and to examine progressive aiding/training requirements for the sonar technician and fire control technician ratings. The algorithm was used to identify major JPA technology gaps in hybrid aiding and complex digital electronics and in defining limitations for the use of JPAs by low-aptitude personnel on troubleshooting tasks.

Plan of Action

The algorithm will be applied to the NATO SEASPARROW System and to the Fire Control and Gunners Mate ratings for selection and demonstration of the most appropriate aiding and training technologies in a JPA-IPS model.

The algorithm will also be refined and included in a more comprehensive multvariate model being developed for cost-performance trade-offs among the various personnel technologies. Ultimately, the algorithm should serve as a useful tool for system planners and developers in considering joint efforts and potential cost trade-offs among aiding, training, selection, and job design technologies.

CONTENTS

LIST OF FIGURES

INTRODUCTION

Problem and Background

Selection and training have been the primary means of ensuring the effective operation and maintenance of machines and systems in the Navy and the other services. However, rising personnel and training costs, decreasing personnel levels, and declining entry-level skills have seriously restricted the effectiveness of these conventional mechanisms for ensuring adequate manning and operational readiness. Experimental and field studies over the past 20 years have indicated that job performance aids (JPAs) can (1) enhance the performance of lesser trained and lesser skilled individuals, and (2) reduce personnel, maintenance, and training costs. Aiding technology, therefore, is now considered complementary to older technologies.

A basic problem is the selection of the best JPA to meet the task, environmental, and personnel needs of particular weapon systems. Researchers, developers, and implementers alike have viewed this problem as a major impediment to the full utilization of JPA technology, and at least six projects in the Army, Navy, and Air Force have addressed it in the past 2 years (Booher, 1977). The glossary lists 101 JPA systems techniques that have been considered for aiding operator and maintenance task performance.

Recent algorithmic approaches to JPA selection have (1) described fundamental elements for low-cost ownership (Shriver & Hart, 1975), (2) organized JPAs into basic format/content types (Post, Price, & Diffley, 1976), and (3) provided matrices of JPA system components under varying task, environment, and personnel factors (Hughes, 1977). These selection models have provided clues to only some of the primary selection factors and have been generally deficient in considering the effects of JPA selection on training and job design.

Purpose

There are several areas in Navy weapon systems and personnel R&D where an algorithm or model that identifies major JPA research and technology gaps would be especially useful. Specifically, Task 1 of the current NAVPERSRANDCEN Performance Aid Test and Evaluation Project (Z0828-PN) requires a feasible method of selecting the most appropriate JPAs for integration into improved personnel and training systems.

The purpose of the present effort, therefore, was to develop an algorithm that could be used (1) to identify JPA research and technology gaps, (2) to identify candidate JPA systems for trade-off analyses of Navy personnel, maintenance, and training, (3) to select specific JPA systems for inclusion in the Performance Aids Test and Evaluation project, and (4) to identify complementary training levels for selected JPA systems.

1

APPROACH

In Booher's (1978) tri-level organization of JPA technology, the JPA system level was considered the most critical for early trade-offs with training and job design. The present effort (1) examined the literature to determine primary JPA selection factors having a solid research foundation, (2) sought to identify critical research gaps, and (3) endeavored to exercise the algorithm with an integrated JPA/training/job design general model. It was expected that the analyses and development of the algorithm would reveal, within key variables, any major JPA technology deficiencies (e.g., equipment type, task complexity, personnel skill levels) that might require further R&D before completing the design of the performance aid demonstration package. To provide a complete selection model at the JPA system level, the algorithm was developed around potential trade-offs based both on existing and hypothetical propositions. To verify its generalizability, the algorithm was applied to three performance aiding scenarios and two Navy ratings. The algorithm development also included efforts (1) to identify and evaluate specifications and guidelines for JPA procurement and implementation, and (2) to highlight areas where information should be gathered for an integrated JPA utilization handbook.

JPA SYSTEM ALGORITHM DEVELOPMENT

General System Model

To integrate JPAs into maintenance and personnel systems, four major technology areas must be considered: (1) selection of JPA format/content types (e.g., FPJPA, FOMM, work packages), (2) training and support requirements for specific JPA systems, (3) media for the storage, retrieval, and display of information, and (4) work-center job designs. These four technologies have been incorporated into a general system model for integrating JPAs, training, and job design (Figure 1).

Before the model can be exercised, data must be provided regarding (1) maintenance philosophy, (2) general type and complexity of tasks, (3) manpower requirements and availability, and (4) expected workload at the operator and repair centers. Although the four technologies (JPA, training, media, job design) are represented as sequential stages in the model, the input data are critical to each stage. For each technology area, the operation and maintenance communities can estimate costs and establish performance requirements. The most critical element of the model is in cost/performance trade-offs. The personnel utilization potential inherent in aiding and job-design technologies make it unlikely that performance will be sacrificed for cost. The major output of the model, when exercised for a particular weapon system, would be the JPA/ training/job design specifications and guidelines applicable to the Integrated Logistics Support package.

Despite the large number of available JPA techniques, less than 25 percent of those listed in the glossary have experimental performance data (Booher, 1978). The following list of those that have such data could be reduced even further, since many are different versions of the same basic type of JPA.

AF/FPJPA	MDC
AAT (hybrid)	Optimum Pic/Word
AMSAS	PIMO
AVIS	XFL
BFIC	Work Package
C-141 Aids	REPOM/MIRM
FEFI/TAFI	RAPIDS
FOMM	Microfiche
FORECAST	MIARS
JOBTRAIN	Implosion
MAINTRAIN	Holograph
MDS	Computer (hand-held)

For example, PIMO, AMSAS, and FPJPA are all forms of the FPJPA. Some are media presentation techniques (e.g., MIARS, RAPIDS, SADIE, WSMAC), while others combine format/content with media and other physical features of the aid (e.g., AVIS, FOMM, FLAPS, REPOM/MIRM). (For a complete breakdown of the various JPA types and methods of classification, see Booher, 1978.) Although there are relatively few proven JPA basic types, each demands very different considerations for selection and introduction into an integrated personnel system. For that reason, an algorithm was developed that requires the use of major decision criteria in selecting the most appropriate JPA for operator and maintenance information aiding.

5

JPA/Training Selection Algorithm

The following are the major decision criteria for JPA selection:

1. Personnel aptitude.
2. Task type being aided.
3. Equipment complexity.
4. Degree of proceduralization.
5. Technician experience.
6. Task complexity.
7. Equipment type.

The decision algorithm diagrammed in Figure 2 illustrates how these criteria
influence the choice of basic JPA types and of corresponding training require-
ments. Because decisions at the systems level are relatively gross with
respect to favoring one type of JPA over another, only two types of tasks need
be considered--troubleshooting (TS) and nontroubleshooting (non-TS). The
breakdown of aptitude, experience, and complexity into three levels--low, mid,
and high--is arbitrary, but accommodates existing research data and current
job assignment practices. The three levels are adequate for identifying critical
research gaps that need to be filled to exercise even a preliminary decision
algorithm.

Equipment type and equipment complexity were combined into one factor be-
cause of their commonality. It may also be appropriate to combine task com-
plexity and equipment into one factor. Proceduralization is accounted for by
the type of JPA selected, which is the most distinguishing feature as one moves
from the FPJPA to the deductive aid forms. Another factor that is similar to
proceduralization is the amount of detail required. Although this factor pro-
vides no unique selection power, it is useful in designing formats after the
basic JPA type has been selected.

The decision algorithm links JPA, training, and experience requirements for
operator and maintenance personnel performing troubleshooting and nontrouble-
shooting tasks. The following statements regarding those factors were the most
logical that could be formulated from the data used to construct the algorithm:

1. Troubleshooting

   a. Low-experienced technicians can troubleshoot, with FPJPA, equip-
ment of any complexity if the task complexity is low and if they have certain
minimum training in basic skills and the use of test equipment.

   b. Low-experienced technicians cannot troubleshoot with FPJPA if
the equipment complexity is relatively high and the task complexity is high.

   c. Low-complexity equipment with intermediate to high job task com-
plexity can be troubleshot by low-experienced personnel with FPJPAs and an
intermediate level of training (e.g., system-specific functional concepts).

   d. Equipment with intermediate to high complexity, with intermediate
task complexity, can be troubleshot by low-experienced personnel with FPJPA
and an intermediate level of training in system-specific functional concepts.

7

Figure 2. JPA training selection algorithm.
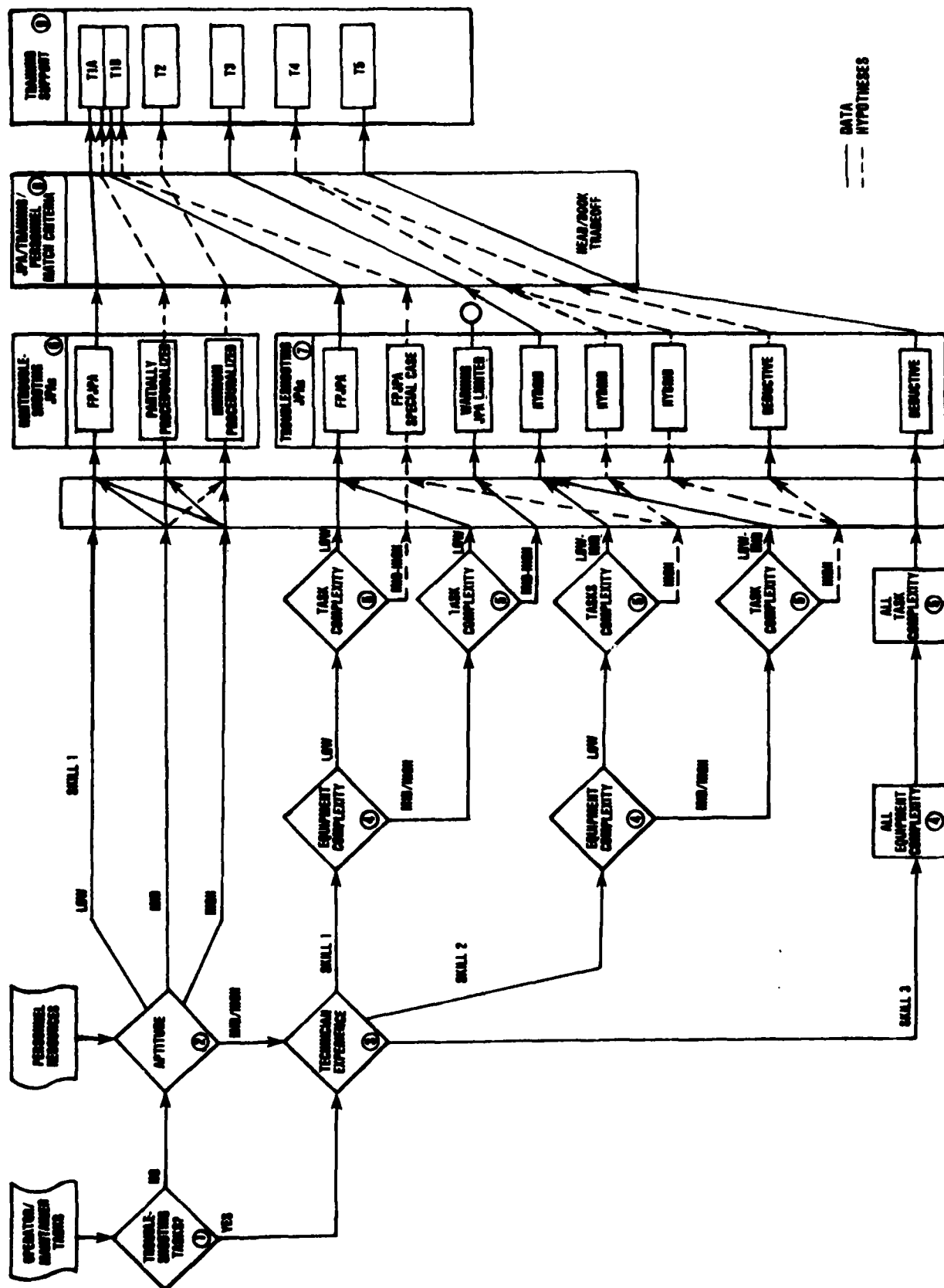
e. Intermediate-level technicians troubleshoot all low-intermediate complexity tasks for any equipment complexity with a combination of directive and deductive aids, an intermediate level of systems specific training, and training in the use of aids (e.g., MDCs).

f. Intermediate-level technicians can troubleshoot all high complexity tasks with a complete complement of directive and deductive aids and a medium level of on-job experience.

g. High-experience technicians can troubleshoot all equipment complexities and task complexities with dependence on low directive and high deductive JPAs and with full training in theory.

2. Nontroubleshooting

a. Technicians of low aptitude levels (GCT equivalent to grade 5) and above can do all nontroubleshooting maintenance tasks and operator tasks with FPJPA and minimum to zero formal training, and with minimum on-job experience.

b. High-aptitude technicians (with past experience) can perform all nontroubleshooting tasks with minimum procedure PPJPAs or FPJPAs, low formal training, and minimum on-job experience.

c. Intermediate-aptitude technicians can perform nontroubleshooting tasks with PPJPAs, low formal training, and minimum on-job experience.

Statements 1a, b, e, and g; and Statements 2a and b, are supported by solid data. The other four statements are considered reasonable but can be treated only as research hypotheses at present. The data are insufficient to extend the algorithm confidently into media selection and job design. General rules and guidelines regarding these areas, however, have been described by Booher (1978).

The decision algorithm diagrammed in Figure 2 includes nine steps, which are grouped under JPA Selection Decision Guidelines and JPA/Training Specifications and Guidelines, and a set of Training Level Choices.

JPA Selection Decision Guidelines

1. Task Type

Troubleshooting--Test equipment setup, operation, alignment-adjustment procedures, fault isolation, signal tracking, remove-replace failed component.

Nontroubleshooting--Operator tasks, preventive inspection, maintenance, servicing, simple repairs, disassembly, assembly, remove-install, calibration.

2. Technician Aptitude

Low--Functional literacy (fifth grade) and spatial ability of minimum level for operator or maintenance activities; for example, at least 40 but not more than 45 on GCT, ARI, and MECH tests. This level has low probability of ever doing more than nontroubleshooting type of maintenance.

9

Mid—Ninth grade reading level or above. Score between 45 and 60 on GCT, ARI, and MECH tests; sufficient aptitude to do nontroubleshooting maintenance and operator activities with partially proceduralized JPA; sufficient aptitude to do troubleshooting with FPJPA.

High—Score 60 or better on GCT, ARI, and MECH tests. Sufficient aptitude to do nontroubleshooting and operator tasks on given types of equipment with very minimum directions and some system-specific OJT. Can do troubleshooting with FPJPA.

Mid-High—Sufficient aptitude to progress in careers with experience and use of JPAs. Should be able to reach level of high-level technician in 3 to 4 years, where troubleshooting can be done with deductive aids only.

3. Technician Experience

Low—Zero to 6 months of actual on-job experience.

Mid—Six months to 1 year of actual on-job experience in specific equipments; 1 to 2 years of job experience on varied equipment types, but no theory.

High—More than 1 year on specific equipment; 2 to 4 years of varied experience across equipment types, having had classroom theory, with special training in use of deductive aids.

4. Equipment Complexity

Equipments with subordinate breakdown greater than 1 in 10 are assumed by one writers' guide to pose complex troubleshooting problems (Post, Price, & Diffley, 1976). This is a very difficult assignment to make, however, and no guidelines are now available. Some of the following information may be helpful in establishing guidelines.

Equipment complexity is primarily a function of how many pieces or parts are required to make it operate reliably. Complexity may vary depending on the type of equipment, (e.g., electrical, mechanical, digital electronics). For job aiding, the lowest subordination for piece-part is the lowest removable component for which spares are provisioned. Interface with other equipment can also increase complexity; for example, if an equipment is functionally tied to other equipments, then it is more complex than if it operated alone.

The level of maintenance for repair will also affect equipment complexity; for example, a piece of equipment that requires procedures only to find and remove a faulty major component (e.g., radar transmitter) would not be considered so complex as if the component had to be repaired without removal. This, of course, touches on the question of task complexity.

5. Task Complexity

Task complexity varies with maintenance philosophy, task frequency, and task difficulty (e.g., requiring precision motor skills, coordination of interdependent tolerance, or alternative forms of accomplishing the action). This could also be a function of maintainability design. A task judged to be complex may be simplified with better design rather than by developing a special-case JPA.

10

Task complexity can be expected to vary widely on any particular system or equipment, so it is sometimes helpful to set comparison reference points by rejecting the most complex, critical, and skill-demanding task and a very simple task. Excessive task length does not necessarily indicate complexity. Generally, complex tasks require sophisticated tools or test equipment, involve measuring or maintaining close physical or electrical tolerances, or involve equipment access that is difficult or not readily apparent.

Task criticality, the probability of an improperly performed task going undetected until it presents personnel or equipment hazard, also contributes to the task complexity factor. For example, a misadjusted aircraft landing gear locking mechanism may not be detected until the aircraft is about to land, so this adjustment would be considered a critical task. Conversely, an improperly installed radar receiver, while rendering the system inoperative, would most likely be detected during a system operational checkout, so the installation task would not be considered as highly critical as the landing gear adjustment task (Middleton, 1977).

JPA/Training Specifications and Guidelines

6. **Nontroubleshooting JPA Specifications and Guidelines**

   FPJPA—MIL-SPEC & handbooks for Air Force FPJPA, MIL-J-83302 MIL-M-38800.
       —Army ITDT, MIL-M-632XX(TM) Part I, MIL-M-63038.

   PPJPA—NAVAIR Work Package, MIL-M-81927.
       —NAVSEA Guide for Selecting Formats and Media.
       —MRC, MIL-M-63030.

   Minimum Proceduralized—NAVAIR Work Package Descriptions and IPB
                         (MIL-M-81927) (MIL-M-81929).
                         —Periodic Maintenance Requirements, MIL-M-23618B.

7. **Troubleshooting JPA Specifications and Guidelines**

   FPJPA—MIL-SPEC & handbooks for Air Force FPJPA, MIL-J-83302, MIL-M-38800.
       —Army ITDT, MIL-M-632XX(TM) Part I, MIL-M-63038.

   PPJPA—NAVAIR Work Package (MIL-M-81927).
       —Army ITDT (MIL-M-63037, MIL-M-632XX).

   HYBRID—No specification available.

   Deductive-Simple Logic—NAVAIR Work Package Functions (MIL-M-81927).
                         —MDC (MIL-M-38799).
                         —SIMM/FOMM (MIL-M-24100 A, B).

   Deductive-System Descriptive—Conventional Technical Publications—
     Wiring diagrams and schematics (MIL-STD-863A).

11

8. JPA/Training/Personnel Match Criteria

    Head/book tradeoff--NADC AR-XXX   (Chenzoff, 1973).

9. Training Support

    Army ITDT--MIL-M-632XX(TM) Part II; MIL-M-63040.
    NAVEDTRA 106A--ISD Guidelines.
    NADC AR-XXX (Chenzoff, 1973).
    AFHRL--TR-76-19, Programmed Instruction.

Training Level Choices

1. T1(A)--Complements FPJPA or PPJPA on nontroubleshooting general operator
and maintenance tasks. Tasks usually include:

    a. Operate/secure.
    b. Clean/lubricate.
    c. Assemble/disassemble.
    d. Remove/replace.
    e. Test/inspect.

    Personnel could be assigned to 0 or I level maintenance but are
usually assigned to 0 level.

    Formal training is primarily self-paced instruction, consisting of
showing how to use JPA, developing certain basic skills (e.g., using tools,
soldering, techniques of removing and connecting), doing special operator
training, using PMS, and performing hands-on practice using JPAs.

2. T1(B)--Same as T1(A) but complements FPJPA or PPJPA in electronics and
also covers:

    f. Test/inspect.
    g. Adjust/align.
    h. Troubleshoot/repair.

    Training is required for the use of using basic test equipment (e.g.,
fundamentals in voltage), current wave form measurements, and any special test
equipment that requires special operator instructions. Training can be self-
paced.

3. T2--Relatively heavy formal training--assumes that no proceduralized
JPA is available. Required before personnel can be assigned to OJT. This
training area can cover special skills required for longer training, such
as difficult operator training.

4. T3--Replaces old "C" School but is highly job-oriented. Teaches
systems concepts, signal flow, functional relationships. Instruction on how
to use more difficult level job aids (e.g., MDCs, hybrid aids). Ability to
find test points and follow signal flow on some schematics. Personnel at this
level can be assigned with hybrid aid to other 0 or I level areas and can cover
75 percent of maintenance actions.

5. T4--Includes formal T3 plus considerable on-job experience with systems. This allows an individual with a hybrid aid or deductive aid to do 90 percent of all maintenance actions on all levels of task and equipment complexity.

6. T5--Advanced formal training--circuit theory, fluid flow dynamics, etc. Complements total deductive JPA with high-level maintenance experience. Qualifies trainee to supervise skill level 2 personnel and works as a backup to isolate high-difficulty faults.

Media and Job Design Selection

Nonprint media seldom offer personnel performance advantages and usually cost more to develop and support. Decisions to use such media are usually based on other requirements (e.g., storage, retrieval, speed of updating). There are performance advantages to nonprint media in meeting some training objectives, but the objectives that must be met in an integrated personnel system (IPS) have not been defined. Costs associated with nonprint media must be provided, however, to fully exercise the cost performance trade-offs mentioned in Figure 1.

Job design offers major cost performance trade-off potential, but it has yet to be experimentally investigated in conjunction with an integrated job aid, personnel, and training system. To exercise the trade-off stage of the model, some workload and skill estimates must be provided. As a minimum, quantifiable information (e.g., 50% of the total workload consists of non-troubleshooting tasks; 25%, routine fault-isolation tasks) should be obtainable from past maintenance engineering analyses on similar equipment, from maintenance design plans, or from equipment maintainability experts. From this information, prediction statements such as "50 to 75 percent of the total workload can be accomplished by Category III first-term enlistees using FPJPA" might be made with some confidence.

If this information were provided for each weapon system, it would then be relatively easy to determine the kind and number of ratings and rates needed in the work center. Alternatively, given a fixed number of ratings and rates and a specified amount of work to be accomplished for a weapon system or work center, the model could also be used to estimate the type of JPA, training, and job design necessary to satisfactorily accomplish the work of the center.

Cost Estimating

Although cost ultimately dictates the limits of choice in the four major technologies, reliable cost data and costing methods for aids, training, and personnel are essentially nonexistant. Accurate pricing tools and cost data, therefore, are major gaps that the performance aids T&E project should attempt to fill. The approach taken in the current effort was to identify factors that affect costs under each technology area and to identify procedures and guidelines that can be used in exercising an IPS cost model.

The following is a list of the major factors that will influence the cost of procuring and using JPAs:

13

JPA (Format/content)

Equipment type.
Equipment complexity.
Quality/detail.
 Equipment analysis.
 Functional analysis.
 Task analysis.
 Behavioral task analysis.
 Intelligibility/comprehensibility.
Printing and distribution.

JPA (Media)

Display production.
Media maintenance.
Information revision/update.
Image quality.
Embellishments.
Color.

Training

School type.
 Facilities.
 Equipment.
 Training materials.
 Type of instructors.
Course length.
 Trainee pay.
 Instructor pay.
 Facilities/equipment usage.
Course size.
 Number of instructors.
 Size of facilities.
 Amount of equipment/materials.
Trainee travel.

Personnel

Number of people.
Rating.
Rank.
Nonsystem costs.

Note that the factors listed under "Quality/detail" offer the greatest variety of choice within a specific procurement. They also vary with the type of JPA selected; for example, functional analysis is not required for nontroubleshooting tasks.

For preliminary cost planning, aiding devices should be classified as troubleshooting or nontroubleshooting. Each class can be further broken down into four categories in accordance with Post et al.'s (1976) classification of aid types,

the most expensive being the FPJPA, and the least expensive being the system description type. With this information and an estimate of how many tasks are to be covered, a good estimate of the total number of pages (or frames, etc.) and unit cost can be made. The costs for any selected JPA can therefore be ascertained with a common pricing baseline.

Braid (1977) provided a very general guideline for comparing the cost of FPJPAs to that of conventional JPAs--roughly three to one. On the other hand, reliable estimates of PPJPA (e.g., the work package) may drop to one to one, so an equal cost differential among aid types cannot be assumed. Estimating the costs of personnel and training associated with a particular job design and level of training is more complicated, and the total costs associated with these areas are several times greater than those associated with aiding. A very small percentage savings in personnel or training costs, therefore, could easily off-set any additional costs for the JPA.

The factor most often used to estimate JPA training support costs is weeks of training. The FPJPA should generally require the fewest weeks, whereas the deductive aid forms would require the most. Once the duration and type of train-ing to support the JPA have been established, the total costs for training related to a specific JPA approach can be computed. This includes instructors, facilities, special equipment and materials, trainee pay, travel, and per diem. Training support for a fully integrated personnel system will depend on more than the specific aiding techniques and trainee aptitude and experience, and may even require training at three or four different levels throughout the trainee's career. The need for facilities, instructors, equipment, and materials might not, therefore, be radically reduced even though initial training time and the number of trainees in a course at one time were reduced using the FPJPA.

The other major costs are for support personnel. It is probably simpler to determine the costs of personnel required to support particular weapon systems or work centers on a 24-hour basis (counting each individual only once and as-sociating him with a particular system or set of systems), than to estimate work hours directly accountable to the performance of a specific system. How-ever, even this becomes extremely complicated because, except in major weapon systems, the people responsible for material, spare parts, and JPAs have little control over expenditures on personnel and training. Therefore, the accounting system for personnel and training costs will not generally be compatible with the accounting systems for specific weapon systems or work centers. When non-accountable but important factors such as recruitment training or needs for career growth are also included, cost trade-offs become even more complicated. With the current limited cost information and knowledge of personnel system effects, it is next to impossible. However, cost comparisons are to be attempted during the performance aid test and evaluation phase of the present project, and to the extent that they are successful, they will serve as guidelines for future costing efforts.

Cost Trade-off Management Guidelines

A modified Task Identification Matrix (TIM) provides a basis for a manage-ment trade-off mechanism at the project level. The TIM has already been a use-ful tool for integrating JPA and training task requirements in the planning and development stages. The total number of techniques need not be large, but the

most critical trade-off decisions must influence subsequent decisions across major organizations (e.g., BUPERS, Naval Material Command, Navy Education and Training Command). For example, some of the potential manning cost savings that result from utilization of the FPJPA should be used to defray the aid's higher logistics costs.

Figure 3 illustrates a summary worksheet for four major cost areas (aiding, training, personnel, and media) that could serve as a preliminary planning and decision-making tool for trade-offs. Operational readiness is a fixed objective to be attained at the lowest combined cost of these areas. The upper categories, I and II, represent higher costs, quality, and experience skill levels; whereas the lower categories, IV and V, represent the lowest experience, skill, quality, and cost levels. In practice, detailed category definitions and guidelines would accompany the worksheet.

The summary sheet should initially be completed using the best estimates that can be obtained from personnel, training, and aiding resources that meet the performance requirements for the weapon system under consideration. If the categories selected were to be included in budgets, funding plans, and policies, they could have major significance and should therefore be selected with greater care. Perhaps recommendations for categories should be made by representatives of the Chief of Naval Operations, Chief of Naval Material, Chief of Naval Technical Training, and Chief of Naval Personnel.

On the worksheet (Figure 3), the information on the work force is probably the best area for initial category assignments. Manning decisions are based on anticipated personnel resources and operational requirements. The item "percentage skill" refers to the conventional skill categories. As shown in Figure 3, the high skills of Category I would be generally low, with II or III probably the highest attained.

Increasing numbers of Category III and Category IV skills in the work force place greater dependence on aiding and training. The item "percentage first term" refers to first-term enlistees and provides a gross measure of job design. For example, if work centers could be designed so that 75 percent of the work were done by first-term enlistees, then personnel costs should be considerably lower than if none of the work could be done by low-experience groups. This might require Category I and II job aids, as shown in Figure 3. With the higher category aiding, relatively low Category IV training would be possible. After the categories for each technology resource have been assigned, specific information from the weapon system (e.g., number of tasks, number of personnel) with appropriate cost data can be used to predict overall costs as well as those for each major support area. Scenarios could be plotted to predict different cost trade-off advantages over time. For example, it would be useful to know the relative differences among the areas at different stages of the life cycle. Initial procurement costs may be relatively high for aiding under a scheme dependent on short training time and high utilization of low skill personnel. The aiding costs should drop considerably thereafter, but training costs may start to rise if training for a career force is considered. Finally, life-cycle cost differentials could be determined through the exercise of appropriate cost models for the trade-off combinations under consideration.

System/Equipment

RADAR ANXXX

CAT	AIDING		TRAINING		WORK FORCE		MEDIA	
	TS	Non-TS	Weeks	Type	% Skill	% First Term	Shore	Ship
I	FPJPA	(FPJPA)	26+	Adv Formal	6	0	Real Time	Real Time
II	(PPJPA)	PPJPA	16-25	Formal	25	25	Audio Visual	Audio Visual
III	Logic Ded	NA	10-15	JOT	60	50	Microform	Microform
IV	Sys Des	Sys Des	(<10)	(TOT)	13	(75)	(Print)	(Print)
V	Eng Dwg	Eng Dwg	0	OJT	NA	100	-	-

Figure 3. Sample worksheet for integrated personnel system cost trade-offs.

Once the major trade-offs have been established, the next problem is one of integrating the technologies to meet IPS and weapon system objectives. Appropriate procedures will be another major item for the IPS guidelines of the performance aids T&E project. As mentioned above, a modified TIM might be especially useful for this procedure at the project level.

Specifications and Guidelines

Application of the selection algorithm ultimately identifies and refines specifications and guidelines appropriate to a particular weapon system. The quality of existing documentation applicable to the design and implementation of an IPS for the Navy is excellent in some categories of JPA technology but is nonexistent for job design, cost determination, cost performance trade-off, and personnel system interface.

For procuring JPAs, adequate specifications exist for the FPJPA and the deductive aids. In the case of the FPJPA, Air Force and Army specifications need modification to fit specific Navy requirements, and this has been done for both nontroubleshooting tasks (Post & Brooks, 1970; Horn, 1972) and for troubleshooting tasks (Theisen & Fishburne, in press) on Navy equipment. There are also some good specifications for the development of PPJPAs, including the maintenance requirement card (MRC) for nontroubleshooting tasks and logic tree approaches (Army, Air Force, and Navy) for troubleshooting tasks. Aiding troubleshooting tasks with simple logic deductives requires a functional task analysis. The NAVSEA FOMM, the NAVAIR work package, and MIL-M-38799 (MDCs) provide adequate specifications for developing deductive troubleshooting functional flow and logic information.

Although some starts have been made toward a hybrid aid (i.e., two or more basic aid forms interconnected to permit choice troubleshooting at more than one aiding level), only one (NAVAIR Hybrid) links proceduralized troubleshooting to deductive troubleshooting. This link is where hybrid aiding would be most beneficial, but further testing of hybrid aiding is needed. If the findings are positive, then a hybrid-aid specification for the IPS will have to be developed.

Many Navy weapon systems utilize computers with a high degree of electronics and electromechanical system interaction. It is often difficult to trace failures to the subsystem or component at fault. The NAVAIR work package is an excellent approach for different interactive systems at the organizational and intermediate levels. Unfortunately, there are no fully adequate JPA approaches for troubleshooting digital systems. Additional development, test, and evaluation of digital aiding techniques should be done before attempting to aid the Skill Level 2 and 3 personnel described in the preliminary IPS model (Blanchard & Laabs, 1978).

Army, Air Force, and Navy documentation is sufficient for task identification and analysis, performance measurement, and JPA/training trade-off requirements. This material exists primarily in the form of guidelines. However, a wide variation in quality can be expected from contractors performing these requirements because Navy standards for evaluating these technology areas have not been established.

The education and training communities can provide the necessary deferred training and hands-on training devices to support the IPS model. NAVPERSRANDCEN's JPA effort will have to develop guidelines for the remaining requirements in job design and in IPS development and implementation.

JPA/Training/Job Design Scenarios

Three scenarios were used to examine the aiding philosophy for the JPA project and to explore cost comparisons for integrated JPA, training, and job design.

Scenario I integrates these three areas using conventional techniques. This approach relies on heavy front-end training, selection or development of highly skilled personnel, and primarily deductive job aids. This scenario envisions improved accuracy and timeliness of conventional documentation (possibly through microforms or other improved media techniques), improved training to deliver higher-skilled personnel to the fleet (thus lowering reliance on OJT), and an improved selection and recruitment process.

Scenario II places a high reliance on FPJPAs. This approach (1) emphasizes greater usage of inexperienced, lower-aptitude personnel, (2) fully proceduralizes all but the most difficult tasks, and (3) relies primarily on first-term enlistees, with some backup from experienced personnel. To replenish the pool of experienced personnel, those who re-enlist would receive advanced training. This approach looks to (1) reductions in initial training costs, (2) improved maintenance, and (3) better utilization of personnel to offset high aiding costs.

Scenario III provides a complement of graduated aids (FPJPA, hybrid, deductive) and decreased front-end training, but a gradual increase in training after initial sea experience.

Figure 4 provides a hypothetical comparison of costs for (1) JPA/technical data (X), (2) individual training (Y), and (3) Navy personnel assigned to work centers (Z). Data from previous JPA studies were used to determine the relative costs of these three areas for each approach. At present, there are no reliable Navy data to relate X, Y, and Z, but Army estimates from Shriver and Hart (1975) indicate that X is small relative to Y and Z. In Figure 4, Scenario I is referred to as the Conventional approach; Scenario II, High Aiding; and Scenario III, Career Development.

JPA/Technical Data Cost Comparison

Costs at initial procurement (X) are expected to triple (3X) for the FPJPA. Career development aiding, which may use FPJPAs or deductive aids, could increase to 4X.
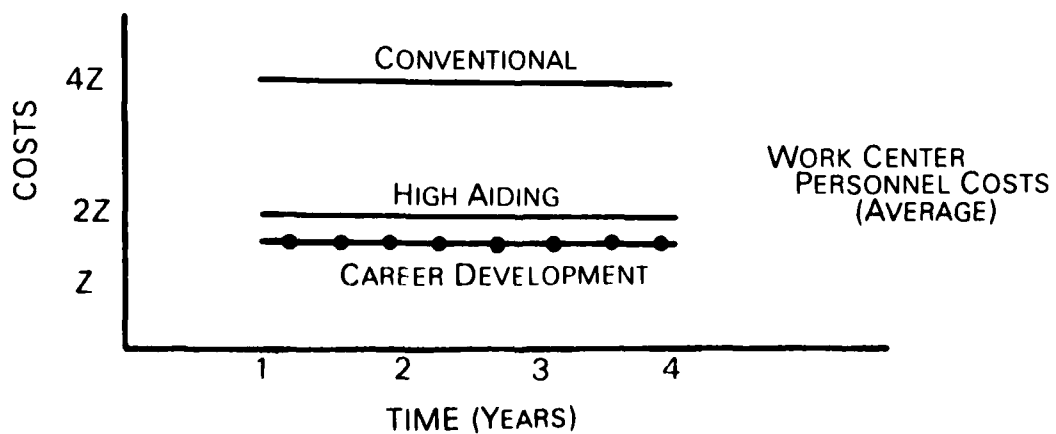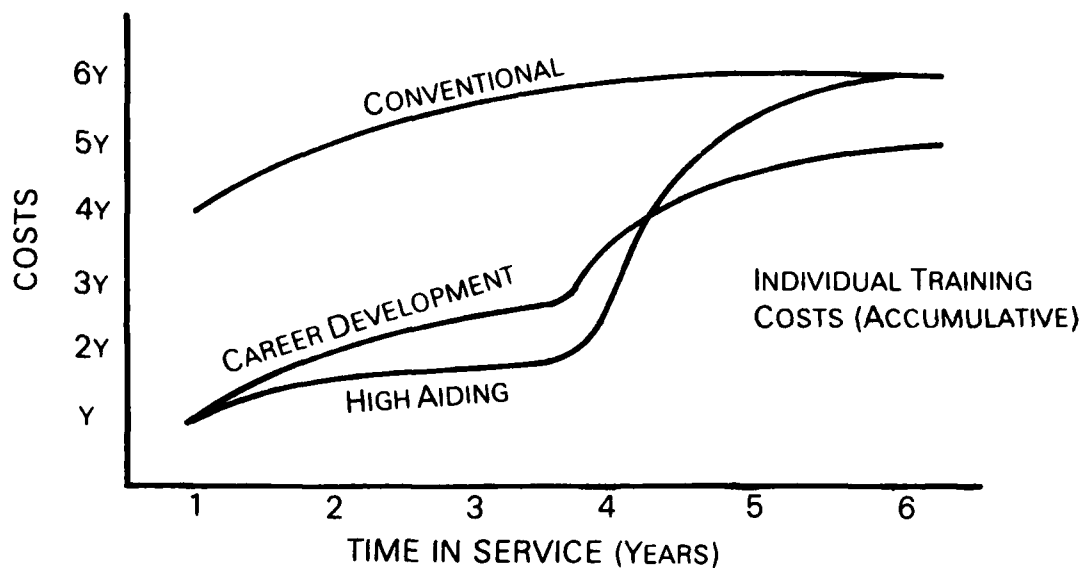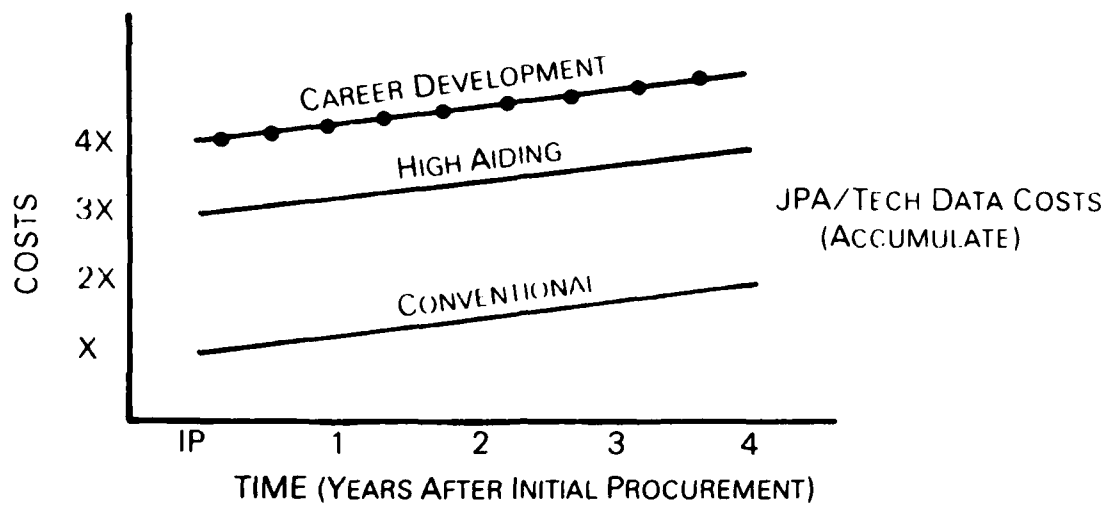
Figure 4. Hypothetical costs for three JPA, training and job design scenarios.

Individual Training Costs

Costs per year (Y) are plotted over a 6-year period that for 6-year obligors, is hypothesized as reaching a maximum of 6Y. The high aiding and career development scenarios predict first-year training costs of about 25 percent of those for current enlistees. High aiding requires relatively little training for the 4-year obligor whose reenlistment costs increase rapidly to provide the skills required for complex troubleshooting. The career development plan gradually increases training and responsibility, and accelerates career advancement during the first enlistment for individuals showing career potential. The high aiding approach reduces overall training costs because of fewer individuals in the front end, where training costs are high. The career development scenario should reduce training costs significantly for all individuals because earlier exposure to complex problem solving will be possible and formal school attendance could be substantially reduced for individuals with earlier maintenance training and job experience.

Work Center Personnel Costs

The comparison of personnel costs for the three scenarios is based on an overall military operational readiness of 50 percent, a 50 percent utilization of first-term enlistees, and the analyses of AMSAS data by Post and Brooks (1970). If 2Z represents current personnel costs for the average work center using conventional techniques, then the 50 percent utilization figure allows the hypothesis that 4Z would raise productivity to 90 to 100 percent. Stated another way, personnel costs (assuming that half are first-term enlistees) associated with the work center could be halved by the number of first-term enlistees with no reduction in productivity (i.e., until experienced people leave the system with no replacements). The high aiding technique allows full productivity with no change in current personnel costs (2Z), or 50 percent productivity with a 50 percent cutback in personnel costs.

Again, only the career development scenario predicts both full productivity and a reduction in personnel costs, assuming that it will produce a 25 percent reduction in total personnel. Improvements in work efficiency should allow a complement of one low, one intermediate, and one highly experienced person, each carrying a significant workload, to replace the conventional complement of two inexperienced and two experienced personnel, where the latter do most of the work. The curves are flat because, if inflation costs are disregarded, it is assumed that work center personnel costs remain relatively stable from year to year.

Analysis

If the assumptions in these scenarios are valid, then both the high aiding and career development approaches are preferable to the conventional one even though initial job-aid procurement costs are expected to be high. The advantages of the career development approach (viz., personnel acceptance, personnel retention and development, and potentially

greater cost savings in training and personnel) make it preferable to high aiding. The major disadvantages are the initial JPA procurement costs and the higher first-enlistee training costs.

Application to Navy Ratings

The career development scenario requires a selection of different JPAs at three competency levels in an individual's career. At present, these levels are simply labled Skill Level 1, 2, and 3. For an individual who displays initiative, these skill levels cover 1/2 to 1-1/2 years, 1 to 3 years, and the 4th year and beyond, respectively. A detailed model defining each level and specific competencies was presented by Blanchard and Laabs (1978).

Table 1 is a compilation of candidate JPA systems that resulted from an exercise using the JPA selection algorithm on the proven JPAs listed on page 5. Figure 5 provides specific examples of troubleshooting diagrams that are applicable to the three skill levels.

For Skill Level 1, which covers the first assignment, the FPJPA is recommended for all operator and nontroubleshooting tasks. The media could be manuals, booklets, maintenance requirement cards (MRCs), microform, or audiovisual displays. The FPJPA can also be used for low-complexity troubleshooting in electrical or electronic systems.

For Skill Level 2, it is recommended that dual-level FPJPAs or PPJPAs be used for nontroubleshooting tasks. The hybrid aid using a PPJPA format as found in work package or logic trees should be used for troubleshooting tasks. Electronic systems require hybrid formats containing branching logic, blocked schematics, functional flow diagrams, regular schematics, narrative/tabular logic, and MDCs. The hybrid aid plus all system description information, such as detailed schematic wiring diagrams, should be provided for Skill Level 3. The FOMM/SIMM and work package concepts are the best available for this level. It is not clear whether experienced personnel can further improve performance with less than the usual formal training, but with Level 1 and 2 personnel doing most of the maintenance tasks, experienced personnel should have more time for diagnosing faults.

Two ratings were selected for applying the JPA selection algorithm to the IPS model. These ratings, the sonar technician (ST) and the fire control technician (FT), are in the surface Navy, requiring strong backgrounds in electronics, and perform operator as well as maintenance functions. Table 2 shows the different JPA and training combinations that resulted in the two ratings when the IPS model and JPA algorithm were pursued across the three skill levels (Phases I, II, and III).

Table 1

Candidate Systems Having Experimental Data
and Appropriate Qualifications Levels

Skill Level 1		Skill Level 2		Skill Level 3	
Job Aid	Application	Job Aid	Application	Job Aid	Application
FPJPA (AF)	Non-TS & Low-complexity TS	FPJPA	Non-TS & Med-complexity TS	FPJPA	Non-TS & Med complexity TS
		AAT (Hybrid)	TS	AAT (Hybrid)	TS
AMSAS (Navy)	Non-TS (Electrical, mechanical, electro-mechanical)	AMSAS	Non-TS	AMSAS	Non-TS
C-141 (AF)	Non-TS (all type systems)	C-141 (AF)	Non-TS & TS	C-141 (AF)	Non-TS & TS
PIMO	Non-TS	PIMO	Non-TS & TS	PIMO	Non-TS & TS
		BFIC/BIFAC	TS	BFIC/BIFAC	TS
		FEFI/TAFI	TS	FEFI/TAFI	TS
		MDS/AVIS	TS	MDS/AVIS	TS
		FORECAST	Non-TS & TS	FORECAST	Non-TS & TS
		JOBTRAIN	TS	JOBTRAIN	TS
		MDC	TS	MDC	TS
		REPOM-MIRM	TS	REPOM-MIRM	TS
		Work Package	Non-TS & TS	Work Package	Non-TS & TS
		LTTA (AF)	TS	LTTA (AF)	TS
				FOM/SIMM	TS
				MAINTRAIN	TS

JPA 1 (Novice)	JPA 2 (Level 2)	JPA 3 (Level 3)
← FPJPA →	← JPA-HYBRID →	← JPA-Deductive →

Existing Formats

FPJPA	PPJPA	Simple Logic Deductive	System Description
MIL-J-83302	Tabular logic tree	MDC	Conventional schematic
MIL-632XX	Branching logic tree	Functional flow	Pictorial schematic
	Symbolic functional	Block functional	Cutaway schematic
	Indicator functional	Symbolic functional	Logic schematic
		Indicator functional	Simplified schematic
			Partial schematic
			Test
			Power distribution
			Wiring digram
			Cable diagram
			Wire list

←————————————————————————→

Block schematic
Pyramid

←————————————————————→

NAVAIR Hybrid

Potential Hybrids

Branching Logic ←————————→ Blocked Schematic ————————→

Branching Logic ←————→ Functional Flow ←————→ Schematic ————→

Narrative/Tabular Logic ←————→ MDC ←————→ Blocked Schematic ————→

Figure 5. Categorization of existing and potential troubleshooting
diagrams into three Navy skill levels.

Table 2

Integrated JPA/Training for ST and FT Personnel Ratings

ST (SQS-26 Sonar)		FT (Mk 86 Gun)	
JPA	Training (Shore)	JPA	Training (Shore)
Phase I			
Level 1 JPA	Sonar Operation	**Level 1 JPA**	Daily System
Sonar System & Ancillary Equipments (Operator & Nontroubleshooting Maintenance)	Ancillary Equipment Operation	Topside Radar, Circuit Boards, Power Supplies (Non-TS)	Operational Tests
	Nontroubleshooting Maintenance	**Level 1 JPA** Troubleshooting SPQ-9 Radar Rec.	Nontroubleshooting Maintenance
			Basic Electronics & Electricity (2 wks)
			Troubleshooting Radar Receiver
Phase II			
Level 2 JPA	BE&E (6 wks)	**Level 2 JPA**	Basic Digital Logic Theory
Power Supply & Tape Recorder (Troubleshooting)	Advanced Maintenance (Power Supply)	Mk 152 Computer (Troubleshooting)	Advanced Maintenance (Mk 152 Computer)
			Advanced Operation
Phase III			
Level 3 JPA	Maintenance Theory	**Level 3 JPA**	Maintenance Theory
Sonar System (Troubleshooting)	Troubleshooting SQS-26	Weapon Control System (TS)	Troubleshooting Mk 86

The breakdown of JPA levels for nontroubleshooting and troubleshooting tasks varies with the rating. To be productive early in his career, the ST must be able to operate not only the main sonar equipment but also several ancillary equipments (e.g., underwater telephone, bathythermograph, fathometer). However, he would not be able to perform much troubleshooting. Conversely, the FT can do very little useful work until he can troubleshoot at least one critical equipment. The ST, therefore, does not receive basic electricity and electronics training until Phase II (after a technical sea assignment), whereas the FT receives a short course (with an emphasis on oscilloscope usage) before his first technical sea assignment.

When ratings are examined across equipments over 4 years, the problems of format standardization and multiple-format coverage on the same equipment may be eliminated because technician capabilities will be expanding from one equipment to several, and from easier to more difficult tasks. With both the ST and the FT, only one format/content system is required for each specific task-equipment combination. For the ST, the FPJPA alone could cover operator and nontroubleshooting tasks on the sonar and on some of the ancillary equipments. It also appears that only the FPJPA troubleshooting format need be used for the FT on the SPQ-9 radar receiver. The FOMM format would be acceptable for the more complex troubleshooting on both the sonar and fire control systems. However, some type of hybrid aid appears appropriate for some of the equipments covered by both ratings at Skill Level 2.

PLAN OF ACTION

The JPA selection algorithm will be applied to the NATO SEASPARROW System and to the fire control and gunners mate ratings for selection and demonstration of the most appropriate aiding and training technologies in a JPA-integrated personnel system model.

The algorithm will also be refined and included in a more comprehensive multivariate model being developed for cost-performance trade-offs among the various personnel technologies. Ultimately, the algorithm should serve as a useful tool for system planners and developers in considering joint efforts and potential cost trade-offs among aiding, training, selection, and job design technologies.

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GLOSSARY

JPA SYSTEMS AND TECHNIQUES

Acronym or Popular Name	Full Title (if different)	Source
AAT	Augmented Action Tree	BioTechnology, Inc.
ADMIRE/MIRAID	Automatic Diagnostic Maintenance Information	Westinghouse Electric Corporation
ADPEP	Automated Data Preparation Evaluation Program	McDonnell-Douglas Aircraft Company
AGCS	Alden Graphic Communication System	Alden, Inc.
AMSAS	Advanced Manpower Concepts for Sea-Based Aviation Systems	Naval Air Systems Command
ATOMS	Automated Technical Order Maintenance Sequence	Boeing Aircraft Company
ATS	Administrative Terminal System	
AVIS	Audiovisual Information System	Letterkenny Army Depot
BFIC/BIFAC	Binary Fault Isolation Chart	Westinghouse Electric Corporation
BLOCK FORM		Air Force Human Resources Laboratory
BRITISH ALGORITHM		British Air Force
C-A LOGICAL PROCESSES		(Various sources)
CATA	Computer-Aided Trouble Analysis	Vought Aeronautics
CMG	Condensed Maintenance Guides	Hughes Aircraft Company
Computer-aided Loop Diagram Representations		Technical Communications

35

Acronym or Popular Name	Full Title (if different)	Source
Computer Graphics and Visual Module System		William A. Fetter
Calculator (hand-held)	Personal Programmable Calculators	(Various sources)
CONSD	Condensed Servicing Data	General Electric Company
CONTEX		VITRO Laboratories
COST	Concentrated Odor Sensing Technique	Illinois Institute of Technology
DACOM	Data Communicator	Letterkenny Army Depot
DATOM	Data Aids to Training Operation and Maintenance	General Electric Company
DSA	Diagnostic Sonic Analyzer	Curtiss-Wright Corporation
DIMATE	Depot Installed Maintenance Test Equipment	RCA
3-D Dynamic Display		(Various sources)
ELECTROCULAR	Electronic Ocular	Hughes Aircraft Company
FASTI	Fast Access to System Technical Information	National Security Industry Association
FEFI/TAFI	Flight Engineers Fault Isolation/Turn Around Fault Isolation	McDonnell-Douglas Aircraft Company
Filesearch System		
FIST	Fault Isolation by Semi-Automatic Techniques	U.S. Navy
FLAPS	Functional Layout and Presentation System	Hughes Aircraft Company

36

Acronym or Popular Name	Full Title (if different)	Source
FOMM/SIMMS/IM/IMP/ IMC/BAMAGAT	Functionally Oriented Maintenance Manuals/ Symbolic Integrated Maintenance Manuals/ Integrated Maintenance/Integrated Main- tenance Package/Integrated Maintenance Concept/Block-a-Matic, a-Gram, a-Text	Naval Sea Systems Command
FORECAST		Human Resources Research Organization
FPJPA	Fully Proceduralized Job Performance Aid	Air Force Human Resources Research Laboratory
GM	Diagnosis and Repair Manual	General Motors Corporation
GPAM	Graphically Proceduralized Aids for Maintenance	Publication Engineers
HAWK Radar Mechanic System Collection Manual		Human Resources Research Organization
Hayden Fault Indicator		A. W. Hayden Company
Holography		Randomline, Inc.
Hybrid Maintenance Aid		Naval Air Systems Command
Imagery Enhancing Technique		Imagetics, Inc.
Implosion		Hoehn and Lumsdaine
Information Retrieval and Display Systems		(Various sources)
ITDT	Integrated Technical Data and Training	DARCOM
JOBTRAIN		Human Resources Research Organization
JPA Assessment Algorithm		Naval Air Systems Command/ North Carolina State
JTG/JTM	Job Task Guide/Job Task Manual	DARCOM

37

Acronym or Popular Name	Full Title (if different)	Source
KINTEL		NSIA
LCI	Learner-Centered Instruction	AFHRL
LGCP	Lexical-Graphical Composer-Printer	
LTS-1/LTS-2	Lincoln Training System	Lincoln Lab MIT
M3DD	Microfilmed Maintenance Manual Data Dissemination	3-M Company
MADAR/GPS	Malfunction Detection, Analysis and Recording System/Ground Processing System	Lockheed-Georgia Company
MAGNACARD		NSIA
MAGNAVUE		Magnavox
MAINTRAIN	Maintenance and Training in Complex Systems	Human Resources Research Organization
MDC	Maintenance Dependency Chart	Naval Sea Systems Command
MDS	Safeguard Maintenance Data System	Western Electric
MEDIA		Bell Laboratories
MEMRI	Maintenance Engineering Management and Repair Information	Republic Aviation Company
Micro-Vue		Republic Aviation Company
MIM	Multi-Image Microfilming	Technical Operations, Inc.
Minicard System		(Source unknown)
MINIDATA		Martin Marietta Corporation
Miracode System		(Source unknown)
MITIPAC		U.S. Navy
MMS	Maintenance Management System	(Source unknown)
MRC	Maintenance Requirements Card	U.S. Navy

38

Acronym or Popular Name	Full Title (if different)	Source
MT Magazine	Maintenance Tips	U.S. Navy
NAMES	Navy Aircraft Maintenance Evaluation System	Naval Air Systems Command
NEOSTYLIZED MANUALS		U.S. Army
NTIPS/NTMS	Navy Technical Information Presentation System/Navy Technical Manual System	Navy Ship Research and Development Center
Optimum Picture/ Word Format		Naval Air Systems Command
PIMO	Presentation of Information for Maintenance and Operatioons	Serendipity, Inc.
Procedures Flow Chart		(Various sources)
PROFILE CARDS		Philco Corporation
PS Magazine	PS—The Preventive Maintenance Monthly	U.S. Army
Pulsed Light Projection		Letterkenny Army Depot
PYRAGRAM	Pyramid Diagrams	Hughes Aircraft Company
Quick Fix		McDonnell-Douglas Aircraft Company
RAPIDS	Rapid Automated Problem Identification Data Systems	Grumman Aircraft Company
REPOM/MIRM	Reliability Prediction Oriented Maintenance/Maintenance Instructions Recorded Magnetically	Naval Ordnance Laboratory
RESTORE	Rapid Evaluation System to Repair Equipment	Martin Marietta
SADIE	Smiths Aural Diagnostic Inspection Equipment	British European Airways
SHOCK ACTION		Human Resources Research Organization

39

Acronym or Popular Name	Full Title (if different)	Source
SPARES Test Capability Report		General Dynamics
TASKTEACH		J. W. Rigney/R. Fromer
TOPP	Task Oriented Plant Practices	Bell Laboratories
Team Training		(Various sources)
TEAMS		Northrup
TRACE	Transistor Radio Automatic Circuit Evaluator	Philco Corporation
TROUBLE LOCATORS		U.S. Air Force
TRUMP/MIARS	Technical Review and Update of Manuals and Publications/Maintenance Information Automated Retrieval System	Naval Air Systems Command
TSP		Lincoln Lab, MIT
VAt	Versatile Avionics Systems Test	Naval Air Systems Command
Videofile System		Hughes Aircraft Company
VIDEOSONIC SYSTEM		Letterkenny Army Depot
WORK PACKAGE CONCEPT		Naval Air Systems Command
WSMAC	Weapon System Maintenance Action Center	McDonnell-Douglas Aircraft Company
XFL	Experimental Fault Locator	J. W. Rigney